

Centrifugal Oil-Free Compressor Overcomes Limitations of Magnetic Levitation Bearing Technology

Frictionless Aero-lift™ bearing technology offers an efficient, robust and reliable alternative to magnetic levitation bearings in oil-free compressors





Abstract

In the air- and water-cooled chiller markets, oil-free compression technology is emerging as a more efficient, quieter, easier-to-apply and lower-maintenance alternative to legacy screw compressors. For original equipment manufacturers (OEMs) and end users of mission-critical chillers used in data center, health care and large HVAC applications, oil management adds costs and complexities to system designs — which typically results in declining energy efficiencies throughout their lifecycles.

In recent years, environmental regulations and sustainability initiatives have driven design changes in air-cooled chillers. OEMs and industry stakeholders are pursuing the next generation of oil-free compression technologies, preferably those that provide high operating efficiencies and simplify application complexities while supporting the imminent transition to lower-global warming potential (GWP) refrigerants.

From a technological perspective, currently available oil-free compressors are enabled by the use of costly magnetic levitation (i.e., maglev) bearings. But this technology also introduces some application challenges and known limitations, most notably: declining performance in warm climates, system design inflexibility and inherent technological complexities.

Copeland has engineered an oil-free centrifugal compression technology that leverages an innovative alternative to the challenges of implementing magnetic levitation bearing strategies. This white paper will demonstrate how Copeland's groundbreaking Aero-lift frictionless bearing technology delivers improved energy efficiency, robust performance, broader applicability and high reliability in full- and part-load conditions for today's demanding air- and water-cooled chiller applications.

Emergence of oil-free compression

Providing essential cooling — and heat recovery in many cases — in data centers, health care facilities and other large buildings typically requires the use of air- or water-cooled chillers, which produce chilled water that gets converted to cool air to provide comfort cooling. Because of the high-tonnage cooling requirements of these applications, large screw compressors have traditionally been deployed. Although reliable and robust, screw compressors also include many known oil management challenges:

- Higher maintenance and upkeep costs and requirements
- Declining energy efficiencies over time
- Increasing risks of performance degradation and potential chiller failure

In recent years, consulting/specifying engineers (CSEs) and facility owners have begun to adopt air-cooled chillers — primarily in response to water availability concerns and associated sustainability impacts. Although an air-cooled chiller with screw compression and a flooded evaporator can deliver efficiency gains, the need for oil return and/or management mechanisms significantly increases system design complexities. A similar system designed with an oil-free compressor can provide the same performance benefits without the added oil management complexities — thereby conserving water supplies and reducing environmental impacts while improving application reliability.

The annual energy consumption of an air-cooled chiller is an important factor in determining both lifecycle costs and its sustainability footprint. Chiller and/or compressor selection starts by matching a building's cooling load

with chiller capacity, and then calculating system lifecycle costs and/or return on investment (ROI) — which includes estimated operational and maintenance costs.

As a result, CSEs are becoming more interested in evaluating air-cooled chiller and oil-free compression solutions that deliver the highest possible energy efficiencies without sacrificing reliability or introducing unnecessary operational complexities. Compressor modulation technologies can provide significant efficiency gains over the operating envelope and allow precise load matching in both full- and part-load conditions. CSEs also seek an air-cooled chiller solution that can achieve these goals in some of the most demanding design conditions, such as the high-lift, warm-climate cooling load requirements found in many data center installations.

It is also important to note that the global phasedown of high-GWP hydrofluorocarbon (HFC) refrigerants is imminently pushing the HVAC industry toward the next generation of new, lower-GWP refrigerant alternatives. The Environmental Protection Agency (EPA), via its recent Technology Transitions rule, has set a maximum GWP limit of 700 for the chiller sector, which will drive the market toward emerging A2L alternatives — many of which have lower-flammability designations under ASHRAE classifications.



Challenges with existing oil-free compression technology

Today's oil-free compressors, which were designed with magnetic levitation technology, contain inherent limitations and operational complexities which OEMs and CSEs have come to understand and expect.

Because multiple permanent electromagnetic bearings are required to levitate the compressor rotor (i.e., shaft), radial and axial proximity sensors are needed to regulate the position of the rotor and sophisticated, on-board compressor controls are required to maintain reliable, frictionless operation. In the event of a power disruption and the compressor is no longer energized, standard auxiliary (non-magnetic) bearings are required to maintain low-speed operation and, through this redundancy, ensure reliable operation. This inherent design workaround can increase compressor costs and application complexities.

Oil-free compressors with magnetic levitation bearings can experience known performance-related limitations:

- Insufficient envelope range for high-lift conditions (i.e., significant cooling in high-ambient)
- Reliability concerns and efficiency loss in part-load, turndown conditions
- Prone to surging (i.e., flow reversal) and choking (i.e., maximum flow) in stop/start conditions
- Short cycling, which can impact cooling performance

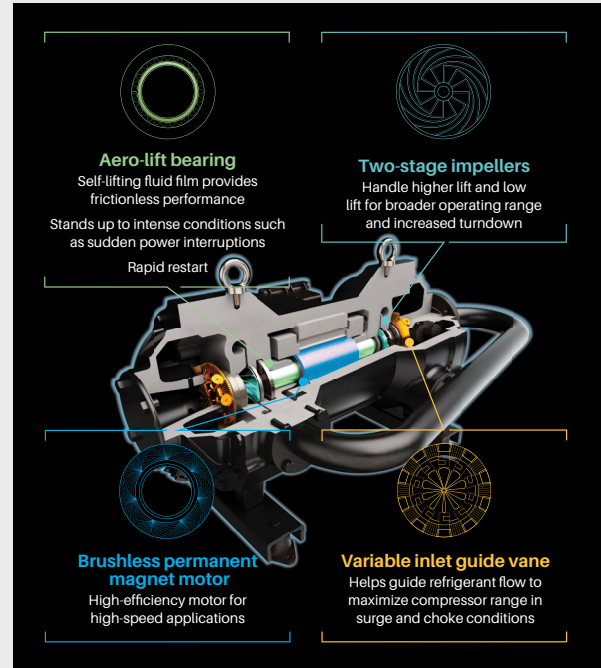
Current oil-free technology relies on the integration of a compressor, on-board controls and a variable frequency drive (VFD). But this pre-configured architecture can present design customization challenges for OEMs who are unable to decouple the compressor from the controls and drive. For example, in a high-ambient, humid climate, this inflexible architecture could create issues with on-board electronics — potentially increasing maintenance, threatening operational reliability, and limiting chiller applicability.

Although oil-free centrifugal compressors with magnetic bearings offer many improvements over legacy compressors, advancements in oil-free centrifugal technologies are raising the standards for chiller performance — delivering high-lift reliability, improved efficiency and sustainability, and a broader application range for the next generation of air- and water-cooled chillers.

Copeland oil-free centrifugal compressor: Aero-lift technology overview

The Copeland oil-free centrifugal compressor leverages frictionless Aero-lift bearing technology to optimize energy efficiency, simplify design complexities, and maximize the performance of air- and water-cooled chillers in demanding high-lift, high-ambient conditions — and in full- or part-load cooling scenarios. This groundbreaking compressor platform is uniquely optimized to address today's air-cooled, data center chiller requirements while offering broad applicability across a wide range of current and emerging applications. The platform is enabled by four key components:

1. **Aero-lift bearing technology** — Innovative Aero-lift bearings enable the compressor shaft to self-levitate and operate independently without complex controls or proximity sensors.
 - Decouples the compressor from the controls and VFD for application flexibility and scalability
 - Supports rapid restarting and smooth coasting to shut down during unplanned power interruptions
 - Eliminates the need for costly, back-up auxiliary bearings for redundancy
2. **Single compressor shaft with two-stage impellers** — Two-stage impellers deliver capacity modulation to precisely match air- and water-cooling load requirements in full- and part-load conditions. Frictionless, single-shaft design improves application integrity in demanding data centers while optimizing efficiencies in full- and part-load conditions.
3. **High-speed brushless permanent magnet (BPM) motor** — Maximizes compressor efficiency and reliability while supporting a wide range of compressor speeds for efficient variable-capacity modulation.
4. **Advanced economization and control algorithms** — Optimize compressor efficiency and performance, protect it from surges, and enable real-time monitoring and predictive modeling.



Lifting air-cooled chiller efficiency and performance

The Copeland oil-free centrifugal compressor with Aero-lift bearing technology was engineered to overcome many of the challenges inherent to magnetic levitation bearings. Based on proven hydrodynamic bearing technology, Aero-lift bearings enable the Copeland oil-free centrifugal compressor to operate independently — without reliance on electromagnetics, proximity sensors and complex controls.

This all-new, oil-free centrifugal compressor platform is being developed for the 50- to 200-ton capacity range and is

optimized for use with the next generation of lower-GWP A2L and A1 refrigerants: R-1234ze, R-515B and R-513A. For air-cooled chiller OEMs and their customers, the platform provides all the advantages of oil-free compression — with added simplicity, energy efficiency, performance and reliability.

Combined with Copeland's legendary standards for reliability, compressor modulation expertise and adaptive compressor control algorithms, the Copeland oil-free centrifugal compressor delivers improvements across key chiller performance metrics.

Energy efficiency

Compared to existing screw compressor technology, the Copeland oil-free centrifugal compressor delivers significant energy efficiency gains in full- and part-load conditions:

- More than 10 percent efficiency increase in full-load conditions
- Up to 40 percent efficiency increase in integrated part-load value (IPLV) — far exceeding the ASHRAE Standard 90.1 efficiency minimum requirements for a two-compressor, 200-ton system

Robust cooling capacity

Meeting the demanding cooling load requirements of mission-critical, air-cooled chiller applications requires high-tonnage, high-speed compressors that can deliver robust, precise and reliable performance. The Copeland oil-free centrifugal compressor is designed to excel in a variety of conditions.

- Delivers high-lift capacity in full-load, high-ambient conditions
- Improves reliability during part-load turndown
- Matches capacity to real-time cooling load demands

Flexible architecture

Independent configuration of compressor, electronic controls and VFDs opens new design options for chiller OEMs, allowing systems to be customized for various and/or specific application requirements. The Copeland oil-free centrifugal compressor decouples the controls and drive from the compressor to liberate OEMs from one-size-fits-all system configurations.

This flexibility enables OEMs to develop customized air-cooled chiller solutions, such as installations in warm, humid conditions. Remote mounting of controls eliminates exposure to the elements, increasing their reliability and lifespan.

Self-levitating, Aero-lift bearing technology simplifies the inherent operational control complexities of magnetic bearing compressors. Neither sensors nor complex controls are required to ensure frictionless operation of the shaft and bearings.

Performance-enhancing algorithms

The Copeland oil-free centrifugal compressor leverages intelligent control algorithms and predictive data models to optimize performance and reliability. By monitoring real-time run conditions, these algorithms fine-tune compressor performance:

- Smoothing out start/stop cycles
- Keeping the compressor within optimum operating range per application requirements
- Detecting abnormal surge conditions and ensuring compressor protection

After **thousands of hours** tested, it has proven to achieve:

Up to **10%** increase in full-load efficiency

Optimized system start and stop cycles through **intelligent control** algorithms

Up to **40%** increase in IPLV above ASHRAE 90.1 2019 minimums

Compatibility with refrigerants R-513A, R-515B, R-1234ze



Copeland™ Oil-Free Centrifugal Compressor

Prepare for the future of air-cooled chiller efficiency and reliability

The Copeland oil-free centrifugal compressor with Aero-lift bearing technology delivers an efficient and reliable oil-free solution for the air- and water-cooled chiller market. For OEMs, it provides a flexible platform from which they can easily customize and adapt to the needs of specific applications — from data centers to heat recovery to health care facilities and high-ambient conditions.

Delivering high-lift performance for demanding air-cooled chiller requirements, the new platform offers stakeholders all the lifecycle advantages of an oil-free compressor with added simplicity, efficiency and reliability. As end users evaluate their future air- and water-cooled chiller equipment selections,

Copeland oil-free centrifugal compressors can help them to meet their sustainability goals and lower-GWP refrigerant requirements.

Today, the Copeland oil-free centrifugal compressor platform is being optimized for use with lower-GWP A2L refrigerants and is being developed for the 50- to 200-ton capacity range.

To learn more about the advantages of Copeland oil-free centrifugal compressors, please contact your Copeland sales representative and visit our [website for future announcements about the innovative platform](#).

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